

METHOD OF EXPANDING HIGH-SPEED SERIAL VIDEO DATA PROVIDING COMPATIBILITY WITH A CLASS OF DVI RECEIVERS

Related Patent Applications

5 This application is related to co-pending U.S. Patent Application S/N 60/296,924, entitled *Method For Adding Additional Data To A Communication Link While Retaining Backward Compatibility* (Attorney Docket No.: TI-33146PS), filed on 06/08/2001 and co-pending U.S. Patent Application entitled *New Encoding Algorithm Providing Compatibility With a Class of DVI Receivers*, (Attorney Docket No.: TI-33399PS), filed
10 on 08/17/2001.

Background of the Invention

1. Field of the Invention

15 This invention relates generally to data encoding, and more particularly to data encoding techniques that expand data to a high-speed serial video link in such a way that it is invisible to existing receivers such that auxiliary data, i.e. an audio data stream, can be transmitted without any knowledge of the capabilities of the video display to receive auxiliary data.

2. Description of the Prior Art

20 The Digital Visual Interface Specification, Revision 1.0 (DVI 1.0), published by the Digital Display Working Group (DDWG) describes an encoding scheme that should be used for transmission of video data across an interconnecting cable in a compliant
25 system. The DVI 1.0 encoding algorithm involves the expansion of 8-bit video data to a 10-bit serial word. During active video times, the video data is encoded, and during inactive video times, two binary signals are encoded. On one channel, for example, these two binary signals are used to represent horizontal and vertical synchronizing signals. For active video, the input word is denoted as D0 through D7 (D0 is the LSB). The serial
30 word is denoted S0 through S9 (where S0 is the LSB and the first bit to be sent).

The algorithm is shown in Figure 1 where '^' is defined as an exclusive-OR operation, TC is a 'Transition Control' bit, and DC is a 'DC Balance Control' bit, as described in further detail herein below.

5 In order to be able to identify active video data from non-active video data, the inventors of the prior art algorithm set forth above identified the number of transitions within the 10-bit word as a key characteristic that could be detected. Furthermore, certain characters could be sent to uniquely identify the LSB/MSB positions within the serial data stream. In order to prevent the active video characters from being misinterpreted, the TC bit is used to reduce the number of transitions within an active data symbol.

Example:

Assume DC=0 (DC has a separate, independent function described herein below), with TC=0, a binary data symbol (LSB)11111111(MSB) would be first encoded as (LSB)10101010(MSB). Since the goal of the algorithm is to minimize the number of transitions for active data, the TC bit must be set (i.e. perform transition control), and hence the character would be fully encoded as (LSB)1111111100(MSB).

Further, if one assumes that the preceding bit in the serial stream has a logic value of '1', it can be shown that all 8-bit input data can be encoded into a 10-bit code with fewer than six 0-to-1 or 1-to-0 transitions.

20 The DC Balance Control bit is used to optionally invert bits S0 through S7 in order to maintain a DC bias close to zero. The goal of the encoder is to transmit exactly the same number of ones and zeros over a period of time. The encoder keeps a running count of the number of ones and zeros that it has transmitted within the current active video period. If there is a disparity between the number of ones and the number of zeros that have been sent, the encoder will adjust the DC Balance Control bit to ensure that the current character, at worst, does not add to this disparity, and typically will cause the disparity to bias itself towards zero.

Example:

30 If the first active data symbol is (LSB)10000000(MSB), the encoder will transmit the serial code (LSB)111111110(MSB). This will accumulate a disparity of +8 (i.e. nine '1's and one '0' have been sent). If the second active data symbol is

(LSB)01000000(MSB), the transmitter can send either (LSB)011111110(MSB) or (LSB)1000000011(MSB). These two characters have individual disparities of +6 and -4 respectively. Since it is desirable to maintain a cumulative disparity close to zero, the second character must be sent; hence the cumulative disparity will become +4 ([+8]+[-4]).

For the purpose of DVI 1.0, there are four synchronization characters that represent inactive video data. The particular value that should be sent depends on the state of the two additional binary signals that are transmitted during inactive video:

Example:

(C1,C0)=(0,0): (LSB)0010101011(MSB)
 (C1,C0)=(0,1): (LSB)1101010100(MSB)
 (C1,C0)=(1,0): (LSB)0010101010(MSB)
 (C1,C0)=(1,1): (LSB)1101010101(MSB)

As described above, each 8-bit word is expanded to 10 bits for transmission. One of the added bits is used for DC balancing, as stated herein before, to allow the signal to be AC coupled as in a fiber optics system. This is done by optionally inverting the 8-bit data to generate more 'ones' or 'zeros' as necessary. The DC balance bit then indicates to the receiver that this inversion took place.

In view of the foregoing, an encoding scheme that simplifies the TMDS encoding algorithm described in the DVI 1.0 specification while retaining compatibility with most existing DVI receivers would provide great advantages over the prior art. An encoding scheme that enhances the TMDS encoding algorithm described in the DVI 1.0 specification such that auxiliary data, i.e. an audio data stream, can be added to a high-speed serial video link in such a way that it is invisible to existing receivers and such that auxiliary data can be transmitted without any knowledge of the capabilities of the display to receive auxiliary data would also provide great advantages over the prior art.

Summary of the Invention

The prior art DVI signaling method performs an 8B/10B encoding for the data being sent on the link. The two additional bits perform specific and distinct functions:

5 1) Bit 8 is used to indicate a transition that the data may go through for the purpose of transition minimization. If the number of transitions ($0 \rightarrow 1$, or $1 \rightarrow 0$) is greater than 4, then the absence of a transition is encoded. In this way, the number of transitions in the transmitted word will always be less than or equal to 4.

10 2) Bit 9 is used to indicate the optional inversion of bits 0 through 7. This inversion is used to ensure that during the transmission of active video, the number of logic 1 and 0 bits sent remains approximately the same.

The present invention is directed to encoding schemes that simplify the TMDS encoding algorithm described in the DVI 1.0 specification while retaining compatibility with most existing DVI receivers. The encoding schemes expand data to a high-speed serial video link in such a way that it is invisible to existing receivers such that auxiliary data, i.e. audio data stream, can be transmitted without any knowledge of the capabilities of the video display to receive the auxiliary data.

15 In one aspect of the invention, a digital visual interface encoding scheme that expands data to a high-speed serial video link such that auxiliary data can be transmitted is implemented without using a Transition Control bit such that the number of transitions is not controlled and such that the active and non-active video cannot be separated based on the number of transitions while retaining compatibility with most existing DVI receivers.

25 In another aspect of the invention, a digital visual interface encoding scheme that expands data to a high-speed serial video link such that auxiliary data can be transmitted is implemented such that a DC balance is not maintained on the associated cable while retaining compatibility with most existing DVI receivers.

30 In yet another aspect of the invention, a digital visual interface encoding scheme that expands data to a high-speed serial video link such that auxiliary data can be transmitted is implemented by expanding of 8-bit video data to a 10-bit serial word such that bit-S8 of the 10-bit serial word is set to both binary levels randomly and

[illegible]

Brief Description of the Drawings

Other aspects, features and advantages of the present invention will be readily appreciated as the invention becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings in which like reference numerals designate like parts throughout the figures thereof and wherein:

Figure 1 illustrates the prior art (DVI 1.0) digital visual interface encoding algorithm;

Figure 2 illustrates an encoding scheme that simplifies the TMDS encoding algorithm described in the DVI 1.0 specification and depicted in Figure 1, discussed herein above, while retaining compatibility with most existing DVI receivers;

Figure 3 illustrates a digital visual interface encoding scheme according to one embodiment of the present invention; and

Figure 4 illustrates a digital visual interface encoding scheme according to another embodiment of the present invention.

While the above-identified drawing figures set forth alternative embodiments, other embodiments of the present invention are also contemplated, as noted in the discussion. In all cases, this disclosure presents illustrated embodiments of the present invention by way of representation and not limitation. Numerous other modifications and embodiments can be devised by those skilled in the art which fall within the scope and spirit of the principles of this invention.

Detailed Description of the Preferred Embodiments

The present embodiments are best understood by first setting forth a short synopsis of the prior art discussed herein before. The Digital Visual Interface Specification, Revision 1.0 (DVI 1.0), as stated herein before, describes an encoding scheme that should be used for transmission of video data across an interconnecting cable in a compliant system. The DVI 1.0 encoding algorithm involves the expansion of 8-bit video data to a 10-bit serial word. During active video times, the video data is encoding, and during inactive video times, two binary signals are encoded. On one channel, for example, these two binary signals are used to represent horizontal and vertical synchronizing signals.

For active video, the input word is denoted as D0 through D7 (D0 is the LSB). The serial word is denoted S0 through S9 (where S0 is the LSB and the first bit to be sent). The algorithm is illustrated in Figure 1 as:

$S0 = D0 \oplus DC$
 $S1 = D1 \oplus S0 \oplus TC \oplus DC$
 $S2 = D2 \oplus S1 \oplus TC \oplus DC$
 $S3 = D3 \oplus S2 \oplus TC \oplus DC$
 $S4 = D4 \oplus S3 \oplus TC \oplus DC$
 $S5 = D5 \oplus S4 \oplus TC \oplus DC$
 $S6 = D6 \oplus S5 \oplus TC \oplus DC$
 $S7 = D7 \oplus S6 \oplus TC \oplus DC$
 $S8 = TC \oplus 1$
 $S9 = DC$

where ‘ \oplus ’ is defined as an exclusive-OR operation, TC is a ‘Transition Control’ bit, and DC is a ‘DC Balance Control’ bit, as described in further detail herein below.

In order to be able to identify active video data from non-active video data, the inventors of the prior art algorithm set forth above identified the number of transitions within the 10-bit word as a key characteristic that could be detected. Furthermore, certain characters could be sent to uniquely identify the LSB/MSB positions within the serial

data stream. In order to prevent the active video characters from being misinterpreted, the TC bit is used to reduce the number of transitions within an active data symbol. Further, if one assumes that the preceding bit in the serial stream has a logic value of '1', it can be shown that all 8-bit input data can be encoded into a 10-bit code with fewer than
 5 six 0-to-1 or 1-to-0 transitions.

The DC Balance Control bit is used to optionally invert bits S0 through S7 in order to maintain a DC bias close to zero. The goal of the encoder is to transmit exactly the same number of ones and zeros over a period of time. The encoder keeps a running count of the number of ones and zeros that it has transmitted within the current active
 10 video period. If there is a disparity between the number of ones and the number of zeros that have been sent, the encoder will adjust the DC Balance Control bit to ensure that the current character, at worst, does not add to this disparity, and typically will cause the disparity to bias itself towards zero.

Example:

15 If the first active data symbol is (LSB)10000000(MSB), the encoder will transmit the serial code (LSB)111111110(MSB). This will accumulate a disparity of +8 (i.e. nine '1's and one '0' have been sent). If the second active data symbol is (LSB)01000000(MSB), the transmitter can send either (LSB)011111110(MSB) or (LSB)1000000011(MSB). These two characters have individual disparities of +6 and -4
 20 respectively. Since it is desirable to maintain a cumulative disparity close to zero, the second character must be sent; hence the cumulative disparity will become +4 ([+8]+[-4]).

For the purpose of DVI 1.0, there are four synchronization characters that represent inactive video data. The particular value that should be sent depends on the
 25 state of the two additional binary signals that are transmitted during inactive video:

Example:

(C1,C0)=(0,0): (LSB)0010101011(MSB)

(C1,C0)=(0,1): (LSB)1101010100(MSB)

(C1,C0)=(1,0): (LSB)0010101010(MSB)

30 (C1,C0)=(1,1): (LSB)1101010101(MSB)

As described above, each 8-bit word is expanded to 10 bits for transmission. One of the added bits is used for DC balancing, as stated herein before, to allow the signal to be AC coupled as in a fiber optics system. This is done by optionally inverting the 8-bit data to generate more 'ones' or 'zeros' as necessary. The DC balance bit then indicates to the receiver that this inversion took place. In view of the foregoing, an encoding scheme that simplifies the TMDS encoding algorithm described in the DVI 1.0 specification while retaining compatibility with most existing DVI receivers would provide great advantages over the prior art. An encoding scheme that enhances the TMDS encoding algorithm described in the DVI 1.0 specification such that auxiliary data can be added to a high-speed serial video link in such a way that it is invisible to existing receivers and such that auxiliary data can be transmitted without any knowledge of the capabilities of the display to receive the auxiliary data would also provide great advantages over the prior art.

Figure 2 illustrates an encoding scheme that simplifies the TMDS encoding algorithm described in the DVI 1.0 specification and depicted in Figure 1, discussed herein above, while retaining compatibility with most existing DVI receivers according to the best mode known by the present inventors. This encoding scheme has been disclosed and claimed by the present inventors in co-pending U.S. Patent Application entitled *METHOD OF ENCODING VIDEO DATA FOR SERIAL TRANSMISSION*, (Attorney Docket No. TI-33399), filed on _____, 20001, assigned to the assignee of the present invention and is incorporated by reference in its entirety herein. As seen in Figure 2, the encoding algorithm can be described as:

$S0 = D0 \text{ } \overline{\text{INV}}$
 $S1 = D1 \text{ } \wedge S0 \text{ } \overline{\text{INV}}$
 $S2 = D2 \text{ } \wedge S1 \text{ } \overline{\text{INV}}$
 $S3 = D3 \text{ } \wedge S2 \text{ } \overline{\text{INV}}$
 $S4 = D4 \text{ } \wedge S3 \text{ } \overline{\text{INV}}$
 $S5 = D5 \text{ } \wedge S4 \text{ } \overline{\text{INV}}$
 $S6 = D6 \text{ } \wedge S5 \text{ } \overline{\text{INV}}$
 $S7 = D7 \text{ } \wedge S6 \text{ } \overline{\text{INV}}$
 $S8 = 1$
 $S9 = \text{INV}$

It can also be seen that the generation of the TC (Transition Control) bit has been removed. The implication is that the number of transitions is not controlled; and hence the active and non-active video cannot be separated based on the number of transitions. Although the INV bit has a similar function to the DC bit in the DVI 1.0 standard, the algorithm for deriving it is very different. In the algorithm shown in Figure 2, no attempt is made to maintain a DC balance on the cable. Instead, the INV bit is set to a '1' for the purpose of removing 'rogue' character sequences; it is set to a '0' at all other times.

Rogue character sequences, as used herein, are defined in two ways as:

1) any character which generates a reserved synchronization character upon encoding, e.g, (LSB) 00111111(MSB) will encode as (LSB) 00101010(MSB); since this is synchronization character (1,0), the INV bit must be set to avoid sending a decodable synchronization character during active video. The encoded stream therefore appears as (LSB)1101010111(MSB) which is not a reserved character; or

2) a sequence of two adjacent synchronization characters appearing in any position across the span of three consecutive stream characters. The present inventors evaluated different DVI 1.0 receivers and found this criteria was used by most of the DVI 1.0 receivers that were evaluated to determine the LSB/MSB position. Two consecutive characters was determined to be significant since this causes an LSB/MSB realignment in the receiver and hence the second synchronization character is fully decoded. Generation of consecutive synchronization characters must therefore be avoided.

Example: (LSB)00000001(MSB), (LSB)11111110(MSB), (LSB)11111100(MSB) would encode as serial stream: (LSB)0000000110(MSB), (LSB)1010101110(MSB), (LSB)1010100010(MSB). It can be seen that the synchronization characters 1101010101 and 1101010100 occur consecutively within the stream; hence this stream is illegal. The algorithm illustrated in Figure 2 would implement the INV bit to generate the stream as: (LSB)0000000110(MSB), (LSB)0101010011(MSB), (LSB)1010100010(MSB), which does not contain an illegal sequence.

The present inventors tested different brands of DVI 1.0 compliant receivers and found most of the brands correctly decoded the algorithm described herein above with reference to Figure 2. In summary explanation of the above, the encoding scheme shown in Figure 2 simplifies the TMDS encoding algorithm described in DVI 1.0, while

retaining compatibility with most existing DVI receivers. The generation of the Transition Control bit has been removed; and although the INV bit has a similar function to the DC bit in the DVI 1.0 standard, the algorithm for deriving it is very different. No attempt is made to maintain a DC balance on the cable. Instead, the INV bit is set to a '1' for the purpose of removing 'rogue' character sequences; otherwise it is always set to a '0'.

Looking now at Figure 3, a digital visual interface encoding scheme is illustrated according to one embodiment of the present invention and that is an extension of the encoding scheme discussed above with reference to Figure 2. The present inventors have found that the S8-bit need not be set to '1' as set forth above in the method described with reference to Figure 2. The inventors have in fact discovered that the S8-bit can be set to both binary levels randomly and independently from the active video data. In this way, the S8-bit can be effectively used for transmission of auxiliary data such as an audio data stream. The encoding scheme shown in Figure 3 can be described as:

$$\begin{aligned} S0 &= D0 \wedge DC \\ S1 &= D1 \wedge S0 \wedge AUX \wedge DC \\ S2 &= D2 \wedge S1 \wedge AUX \wedge DC \\ S3 &= D3 \wedge S2 \wedge AUX \wedge DC \\ S4 &= D4 \wedge S3 \wedge AUX \wedge DC \\ S5 &= D5 \wedge S4 \wedge AUX \wedge DC \\ S6 &= D6 \wedge S5 \wedge AUX \wedge DC \\ S7 &= D7 \wedge S6 \wedge AUX \wedge DC \\ S8 &= AUX \wedge 1 \\ S9 &= DC \end{aligned}$$

where AUX is an auxiliary data bit that can change every word.

Figure 4 illustrates a digital visual interface encoding scheme according to another embodiment of the present invention that can be defined as:

$S0=D0^{INV}$

$S1=D1^{S0^{INV}}$

$S2=D2^{S1^{INV}}$

$S3=D3^{S2^{INV}}$

5 $S4=D4^{S3^{INV}}$

$S5=D5^{S4^{INV}}$

$S6=D6^{S5^{INV}}$

$S7=D7^{S6^{INV}}$

$S8=AUX$

10 $S9=INV$

where AUX is an auxiliary data bit that can change every word. The present inventors found that while both coding schemes worked, the method shown in Figure 3 was found to provide compatibility with existing DVI 1.0 receivers, while the method shown in Figure 4 was found to require a change to all DVI 1.0 receivers to allow for correct data recovery. It can be appreciated that the particular encoding method employed will then be at the discretion of the system integrator in conjunction with the silicon vendor.

Both methods of expanding video data, discussed above with reference to Figures 3 and 4, successfully generate a serial word suitable for transmission across a high-speed video link in a digital visual interface compliant system. The methods comprise the steps of:

encoding a plurality of active video data bits (D0-D7) to generate all of the bits (S0-S7) other than the two most significant bits (S8 and S9) of a serial word;

25 setting the next to the most significant bit (S8) of the serial word to a binary level randomly and independently of the active video data bits (D0-D7) wherein the next to the most significant bit (S8) is determined in response to an audio data stream; and

setting the most significant bit (S9) of the serial word to a binary level determined by a control bit selected from the group consisting of a DC Balance Control bit and a rogue character sequence removal (INV) bit

30 Looking again at Figure 3, bits S0-S7 of a serial word (S0-S9), are expanded in association with a DC balancing bit 'DC'. Specifically, bit S0 is generated from bit D0

of the active video data and the DC Balance Control bit. Bit S1 of the serial word is then generated from bit D1 of the active video data, the generated bit S0, an auxiliary data bit discussed herein before, and the DC Balancing Control bit, also discussed herein before. This process is similarly repeated to generate bits S2-S7 of the serial word. Bit S9 of the serial word remains a DC Balancing Control bit, similar to the scheme discussed above with reference to Figure 1. Bit S8, however, is generated from auxiliary data since the present inventors have found that this bit can be set to both binary levels randomly and independently from the active video data stream while still retaining compatibility with existing DVI 1.0 receivers.

Looking again at Figure 4, bits S0-S7 of a serial word (S0-S9), are expanded in association with an inversion bit 'INV' discussed herein before in association with 'rogue' character sequences and particularly with reference to Figure 2. Specifically, bit S0 is generated from bit D0 of the active video data and the INV bit. Bit S1 of the serial word is then generated from bit D1 of the active video data, the generated bit S0, and the INV bit. This process is similarly repeated to generate bits S2-S7 of the serial word. Bit S9 of the serial word is simply the INV bit, while bit S8 is generated from auxiliary data. The encoding scheme discussed above with reference to Figure 4 was found by the present inventors to require a change to all DVI 1.0 receivers to allow for correct data recovery. The encoding scheme depicted in Figure 3 was found therefore to be more preferable of the two schemes due to its compatibility with existing DVI 1.0 receivers.

This invention has been described in considerable detail in order to provide those skilled in the digital visual interface signaling art with the information needed to apply the novel principles and to construct and use such specialized components as are required. In view of the foregoing descriptions, it should be apparent that the present invention represents a significant departure from the prior art in construction and operation. However, while particular embodiments of the present invention have been described herein in detail, it is to be understood that various alterations, modifications and substitutions can be made therein without departing in any way from the spirit and scope of the present invention, as defined in the claims which follow.